# Year 1: I$^3$: Towards and Institute for STEM Education

Project Objectives (Five Year):
I$^3$ at the University of Colorado, Boulder works primarily to integrate three existing lines work supported by NSF: (1) efforts in undergraduate and graduate course transformation, (2) programs in undergraduate and graduate teacher preparation, and (3) discipline-based education research among faculty, students, and post-doctoral scholars. Notably, each of these three lines of inquiry into STEM education supports the other two. One of the distinctive aspects of these multi-disciplinary efforts at CU Boulder is that they are located largely in the disciplinary and education departments, rather than in an external center or department. This I$^3$ effort builds on the efforts to integrate programs to build a *distributed* Center of STEM education research and transformation. This Center for STEM education will: (a) integrate the three lines of inquiry and development described above, (b) retain the status and rigor offered through science and engineering departmental identity, and (c) expand the reach of thriving STEM education community to include more departments and participants. The five year I$^3$ program is designed to establish CU Boulder as a national hub of STEM Education by broadening participation, bridging critical educational junctures, developing a better prepared workforce, and integrating discipline-specific education and research, all in the context of a sustainable model of institutional practice which integrates multiple efforts in STEM education.

The first year of this project (2008-2009) has been spent building a foundation for this endeavor. Our efforts can be classified into: programmatic efforts, evaluation, policy work, and travel/ dissemination.

On the programmatic side we are primarily focused on building networks of scholars across the Boulder campus to foster STEM education research and reform. These programmatic efforts are supported by a newly instituted, weekly, Discipline Based Education Research (DBER) seminar series, a weekly project management team meeting, graduate stipends, faculty support, and preliminary development of cyber-infrastructure – a website. Evaluation, at its preliminary stage has focused on identifying existing efforts, the success of these efforts, and the level of integration and coordination among them. Policy work, to establish a state-sanctioned Center or Institute is underway, where senior administration and state officials have been made aware of these plans to establish such a center – response is universally positive. Travel funds have allowed the PMT to share information about the Colorado approach to STEM education research and reform, as well as host a variety of key members of the STEM education community from across the country and abroad here in Boulder.

**Description of Activities:**
The ***Discipline Based Education Research seminar*** is firmly established and meets weekly. DBER brings together faculty and graduate students from over 10 disciplinary departments and three Schools. Over 20 faculty are involved and represent 18 NSF grants. This DBER group, provides a forum for faculty, grads and staff to share ideas about their programs, learn about each other's efforts, provide constructive and critical feedback, and plan interdisciplinary research

programs. These meetings have been effective at creating community among researchers on campus and have also served as an effective forum for working meetings. For example, the DBER group has advised the Colorado Department of Education on K12 science standards. DBER is also serving as a vehicle to make connections with STEM education experts from other institutions and has already hosted faculty from MIT, University of Maryland, University of Hawaii (I$^3$), Open University, England, and the University of Pittsburg.
A complete list of DBER meetings and topics can be found at:
http://www.colorado.edu/ScienceEducation/

The ***Project Management Team*** also meets weekly. The project management team has met to discuss the design and implementation of the project. These meetings have led to: the construction of our website; design, call, review and award of graduate stipends and faculty awards; evaluation structure and approach; hiring of staff; organization of annual symposia; and political advocacy.

This I$^3$ grant has supported 2 ***graduate students in their research on STEM education*** during the spring semester. This grant supports graduate students to conduct design and evaluations on educational innovations, and fundamental studies in education research, such as source and impacts of the gender gap in introductory science courses. This grant has provided partial support for research that has led to two journal publications. Beginning this summer, ***7 PhD students will be supported*** by this grant representing graduate students from Physics, the School of Education, Astrophysics, Math, and Atmospheric and Oceanic Sciences. Their research includes course evaluation, curriculum development, and continuing work on the gender gap in physics. These appointments are funded both directly from this grant and from matching support from the University of Colorado. A full listing of the students and their proposals can be found on www.Colorado.Edu/ScienceEducation/.

The first round of ***faculty funding*** had been awarded and will begin this summer to support 4 faculty with up to $10,000 each to provide course release, summer salary, or research funding to initiate a program in educational research or simply to engage in a discipline-based educational research project for the first time. Proposals represented researchers in Physics, Astrophysics, Education, Chemistry, Mathematics, Biology, Mechanical Engineering, and Aerospace Engineering. Four awards were made comprising both Junior and Senior Faculty. The I$^3$ community (members of the DBER seminar) are using this program to support their submissions for NSF CCLI proposals – In the May submission, the Colorado I$^3$ community submitted proposals from physics, chemistry, environmental sciences, geosciences, and computer science. A complete list of Faculty Awards and their proposals can be found on www.Colorado.edu/ScienceEducation/.

One full time ***project administrator***, Ms. Jordan Brown, has been hired, with matching funds from the university. Ms. Brown keeps records of all grant activities, expenditures, participation in events (such as DBER meetings), manages the web, applications for funding (grads and faculty), and keeps notes of all meetings (DBER, PMT). Serving as project administrator (under the supervision of the PMT and external evaluator), Ms. Brown is also serving to conduct ***initial***

***baseline evaluation*** of the project by identifying all programs on campus in STEM education, and assembling a survey (based on the Hawaii I-3 program and the Association of Public and Land-grant University's effort on systemic change) to identify levels of engagement and integration of STEM educational programs on campus.

Our ***external evaluator***, Dr. Scherr, has already had one meeting with the Project Management Team and will spend a week housed at Colorado in Summer 2009. Dr. Scherr has advised on the mechanisms for collecting baseline data and the summer meeting will flesh out the details of our 5-year evaluation plan.

Plans for a ***Fall Symposium*** on August 30$^{th}$ and 31$^{st}$ are underway where participants in the I$^3$ community will share current and future projects. This interdisciplinary, campus-wide program will serve to build community, raise awareness for STEM and identify key needs within the Colorado community for STEM education. The Symposium will also be attended by Regents, key legislatures and University Administration. Their participation will help support our

We have a ***new website*** devoted solely to STEM Education that will later be built into a portal for program participants to share information and research and serve as a community portal for the proposed Center. This website currently serves to announce meetings, link communities at Colorado, advertise the graduate and faculty awards, and archive events supported by program. It can be found at www.Colorado.edu/ScienceEducation/.

On the ***policy and publicity*** sides of the Colorado I$^3$ effort, members of I$^3$ Project Management Team have given roughly a dozen talks about I$^3$ in national venues (see below). Members of the PMT have met with members of the Colorado state legislature (Rep. Hullinghorst, Sen. Heath, Sen. Palmer and Rep. Levy), members of the Colorado Department of Education (Cartwright), University Regent (Neguse), and have secured invitations to speak to state-level policy makers about the I$^3$ efforts at the University of Colorado. The I$^3$ efforts are scheduled to be highlighted in a visit by the U.S. Congressional Delegation (Rep. Polis, Sen. Udall, Sen. Bennett) to the University on August 18.

In recognition of our efforts in STEM education, the Association of Public and Land Grant Universities (APLU, formerly NASULGC), hosted their ***first annual Science and Math Teacher Imperative*** on our campus May 17-20. This conference brought together leadership from 73 institutions that have committed to preparing more well trained science and math teachers. Members of the I$^3$ project management team were invited to present a panel on the I$^3$ endeavor and the Colorado approach to teacher preparation, which was considered a highlight of the program. This conference provided a valuable opportunity to engage legislative representatives in supporting the I$^3$ efforts. More about the conference and CU's participation can be found at http://www.teacher-imperative.org/.

In addition to CU- I$^3$ program hosting a wide variety of visiting scholars in mathematics and science education, the CU-I$^3$ team has been invited to give 26 addresses across the country (see below). These addresses at universities and national meetings have provided the opportunity to

publicize the CU-I$^3$ efforts as well as learn from other models of integrating STEM education programs on campuses.

**The intellectual merit** of this endeavor lies in the support and growth of the university commitment to and success in STEM educational transformation and education research. This five year program employs innovative approaches to synthesizing and growing commitment to STEM education by supporting participants in discipline-specific educational research and transformation within the home departments, while creating an interdisciplinary community of scholars dedicated to research-based educational improvement. The distributed center will capitalize on physical, social, and cyber infrastructure to build and sustain a University-wide model for science education research and effective practice.

**The broader impact** of this I$^3$ program is the national impact of the resultant Center's research-based, tested, and disseminated innovation in STEM educational practice. This effort will capitalize on the synergies of existing STEM education efforts at CU Boulder, which have already: produced dramatic increases in the numbers of students engaging in STEM teaching (K12 to college), transformed research-based education practices in undergraduate STEM courses, and seeded the growth of new fields of STEM discipline-based education research. This I$^3$ program will provide a model for other research universities seeking to leverage modest resources to integrate synergistic projects on their campuses.

**Reviewed Journal Articles / Book Chapters**

1. C. Baily, and N.D. Finkelstein, " Development of quantum perspectives in modern physics," Phys. Rev. ST Phys. Educ. Res. 5, 010106 (2009).
2. L. Kost, S.J. Pollock, and N. Finkelstein, "Characterizing the gender gap in introductory physics," Physical Review ST: Phys Educ. Research, 5, 010101 (2009).
3. Klymkowsky, M.W. & E.M. Furtak. 2009. Incoherent science and mathematics education undermines biological literacy. Colorado Higher Ed News, published on line March 2009.
4. Garvin-Doxas, K. & M.W. Klymkowsky. 2008. Understanding randomness and its impact on student learning: lessons from the Biology Concept Inventory CBE Life Sci Educ **7**: 227-233.
5. Klymkowsky, M.W. & K. Garvin-Doxas. 2008. Recognizing student misconceptions through Ed's Tools and the Biology Concept Inventory. PLoS Biology, **6**: e3.

**Reviewed Conference Proceedings:**

**Invited Talks:**

1. Otero, V., Talbot, R., Finkelstein, N., Gray, K. (2009). A Longitudinal Study of Pedagogical Content Knowledge: Synthesizing our research on content, pedagogy, and practice. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Garden Grove, CA, April 17-21.
2. Otero, V. (2009). Computer Simulators as a Tool for Helping Elementary Teachers Appropriate Norms and Practices for Model Building in Science. Paper presented at the

annual meeting of the American Educational Research Association, San Diego, CA., April 13-17th.

3. Talbot, R., Briggs, D., & Otero, V. (2009). Can Science Teachers' Strategic Knowledge be Conceptualized as a Learning Progression? Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA., April 13-17th.
4. Otero, V. (2009). Building the base for a focus on learning: the critical role of undergraduate science experiences in science teacher preparation. Presented at the annual meeting of the American Educational Research Association, San Diego, CA., April 13-17th.
5. N.D. Finkelstein, "Reconsidering Tools in STEM Education: The Use of Analogy and Representation," Department of Mathematics and Science Education, School of Engineering and Sciences, Clemson University, April 24, 2009. [invited]
6. N.D. Finkelstein, "Scholarly Education: Implications of Physics Education Research" GAANN Retreat, School of Engineering, University of Colorado, Apr 16, 2009. [invited]
7. M. Cole, R. Lecusay, and N.D. Finkelstein, " Using Cultural-Historical Theories of Activity to Promote Science in After- school Learning Environments" Third Springer Forum on Cultural Studies in Science Education Center for Research in Mathematics & Science Education San Diego State University, April 12, 2009
8. N.D. Finkelstein, " Educating Scientifically: Tools, Practices, and of Physics Education Research," Physics Department, Uppsala University, Uppsala, Sweden, Feb 26, 2009. [invited]
9. C. Henderson, A Beach, N.D. Finkelstein, "An Overview of the Four Core Categories of Change Strategies for Reforming STEM Instruction", invited talk, AAPT/AAAS Winter Meeting, Chicago, IL, Feb 14, 2009.
10. N. D. Finkelstein, "Understanding When and Why Education Works: the role of new technologies in physics education, " *Joint Annual Meetings National Society of Hispanic Physicists National Society of Black Physicist, Nashville, TN, 13 Feb 2008*
11. V. Otero and N.D. Finkelstein, " Transforming undergraduates physics course using Learning Assistants," 2009 Physics Teacher Education Coalition Conference, Pittsburgh, PA, Mar 13, 2009.
12. C. Henderson and N.D. Finkelstein, " Facilitating Change in Undergraduate STEM: The Need to Problematize and Improve Our Approaches to Change," 2009 Physics Teacher Education Coalition Conference, Pittsburgh, PA, Mar 13, 2009.
13. N. Finkelstein, "Educating Scientifically: Tools, Practices, and Implications of Physics Education Research," AAPT Mexico National Conference, Monterrey Mexico, Dec 12, 2008. [invited keynote]
14. N. Finkelstein, "University Community Partnerships in Informal Science Education," Breaking through Walls, Service Learning Symposium, University of Colorado, Oct 29, 2008. [invited]
15. N.D. Finkelstein, "Representations, Analogies and Learning Physics," University of California San Diego and San Diego State, MSED program, Oct 21, 2008. [invited]
16. N. Finkelstein, "Learning Assistants at CU-Boulder," Physics Teacher Education Coalition and NW Regional Meeting of the AAPT, Oct 10, 2008 [invited plenary]"
17. Klymkowsky, M.W. 2008. "Why the 'atheist/ID' THINK! public lecture matters scientifically, historically, politically, and academically. Coffee talk to Philosophy

Department, UC Boulder. December 9, 2009.

18. Klymkowsky, M.W. 2008. "New ideas for recruiting and training science and meth teachers: a catalyst to improve science education from K to 16. [invited keynote speaker] The Philadelphia Education Fund December 12, 2008.
19. Klymkowsky, M.W. 2009. "Key physiochemical concepts in the biological sciences" AAAS Annual Meeting symposium [invited speaker]. February 2009.
20. Klymkowsky, M.W. 2009. "Unrecognized conceptual hurdles to understanding evolutionary biology" AAAS/AAPT joint symposium. February 2009.
21. Klymkowsky, M.W.. 2009. Being scientifically literate and thinking scientifically: what it means, how it impacts our lives, and how its and can be taught. Invited speaker, Darwin Day Celebration Seminar Series, University of Colorado, Denver.
22. Klymkowsky, M.W.. 2009. Being scientifically literate and thinking scientifically: what it means, how it impacts our lives, and how its and can be taught. Invited speaker, UC Boulder library staff seminar. April, 2009
23. Klymkowsky, M.W. 2009. "Key physiochemical concepts in the biological sciences" Invited workshop participant, American Biochemistry and Molecular Biology Society Annual meeting, New Orleans, April 2009.
24. Klymkowsky, M.W.. 2009. "Understanding evolution: a multidisciplinary educational challenge." Plenary speaker, 11th Annual Chicago Symposium series on Excellence in teaching mathematics and science: research and practice. March 6th 2009.
25. Klymkowsky, M.W. 2009. "Designing effective educational scenarios for science and math teachers." workshop organizer, 11th Annual Chicago Symposium series on Excellence in teaching mathematics and science: research and practice. March 6th 2009.
26. Klymkowsky, M.W. 2009. "How and why to teach scientific literacy" invited speaker, Boulder Kiwanis Club, 1 June 2009.

**Contributed Talks/Papers: 2008-2009**

22 papers related to I³ efforts are available at: http://www.colorado.edu/ScienceEducation

**Partnerships / Outreach**:

I³: Towards a Center for STEM Education serves as an umbrella organization for existing STEM Education programs on the University of Colorado Campus. As such it also serves to coordinate Partnerships from a variety of other programs.

Most notably the I³ supports:

***PISEC***: Partnerships in Informal Science Education in the Community, a community program with support from complementary projects (the NSF Physics Frontier Center at JILA, the Colorado PhysTEC program supported by the APS, AIP and AAPT, and CAREER). PISEC partners with MESA and the I Have a Dream Foundation (impacting 30 low income middle school students; 90% second language learners) the Boulder Charter Prep High School program (impacting 20 at-risk high school students each week), Casa de la Esperanza (impacting a dozen children, all second language learners), and a remote video-supported afterschool program at Town and Country Village Housing Project Learning Center in San Diego (a parallel program to the Casa de la Esperanza, impacting another dozen children in inner city San Diego).

***The Math Department*** has partnered with *Boulder Valley School District* to bring over 50 math majors and graduate students into three local elementary schools on a weekly basis to support math teachers, set up math clubs, and administer after school activities. This project is overseen by Professor Eric Stade, project manager for I$^3$.

***STEP 1 and STEP 2*** courses place undergraduate STEM students in the K12 school settings as part of the CU Teach program on campus. These efforts impact 75 undergraduates and over 400 K12 students. This coming year, with coordinating support of I$^3$, PISEC will partner with CU Teach to add an informal science education component.

A premier outreach program at Colorado, ***Science Discovery***, runs school visits, summer camps and university community partnerships. CU Science Discovery annually serves over 30,000 students and 1,500 K12 teachers across the Sate of Colorado. This is accomplished through an array of summer and academic year programs for K12 students, including an over-night summer camp for grades 3-11 and an Outdoor Classroom that brings inner-city kids from Denver into the mountains to learn about ecology and the environment for a day or overnight. They also offer annual professional development workshops for science teachers and curriculum tools that encourage hands-on learning and real-life application.

I$^3$ has also worked extensively with the ***Colorado Department of Education*** to assist and advise them in the transformation of the State Science Standards. A Department of Education representative has presented at DBER and DBER faculty have coordinated in small-working groups on multiple occasions to revise the standards and various stages. This process is still underway, but to date DBERS work has helped to redefine the structure of the standards to more clearly integrate overarching themes and specifically revise the standards relating to scientific investigations and the Nature of Science. The DBER team had also identified concepts that are missing from the standards and is currently working on integrating information on design and engineering in to the standards.

**Training:**
This project explicitly serves to support the development of faculty, postdocs, graduate students, undergraduates and staff relating to STEM educational issues.
Each of the activities described are designed to support the development of:

- undergraduates: more than 3000 undergraduates are impacted in this time frame by educational reforms that are under the umbrella of this program
- graduates: a dozen graduate students in the DBER education community are supported intellectually as they pursue efforts in educational reform and research. For the first half of this year, two graduate students were explicitly supported; an additional 5 will be supported by the end of summer 2009.
- Postdoctoral programs: 8 postdoctoral Fellows, particularly through the Science Education Initiative
- 20 different faculty participate in the weekly DBER meetings; 4 faculty have received support as of summer 2009 under I$^3$ to conduct research and reform under I$^3$ mini-grants.

In another project, efforts continue with the NSF supported Center for the Integration of Research Teaching and Learning (CIRTL), Wisconsin and Michigan State. This work complements the longstanding work on the NSF-supported Colorado Learning Assistant program and its expansion with funding from the National Mathematics and Science Initiative

**Contributions to within the principal discipline(s) of the project**
This project contributes to efforts to conduct educational research and reform in STEM. It expands the theoretical and experimental research and reform base of fields in STEM. (See rest of project report)

**Contributions to other disciplines of science or engineering**
These efforts improve the education of students more broadly and contribute to the long-term improvement of science and engineering. At University of Colorado, efforts are underway to establish education research programs in biology, astronomy, geosciences, chemistry and engineering. Many of these efforts are linked, improved, and informed by the weekly DBER seminar series.

**Contributions to the development of human resources**
These efforts have contributed to the development of a nationally recognized program in STEM education at Colorado The research program has contributed directly and indirectly to the support and development of over a dozen graduate researchers, 10 postdocs in STEM education, and many faculty now engage in scholarly approaches to physics education.

The outcomes of the research are improved education, with an improved undergraduate and graduate curriculum at the University of Colorado physics. STEM K12 teachers are being recruited and prepared in larger numbers than have ever been seen in the University of Colorado history.

**Contributions to the physical, institutional, or information resources that form the infrastructure for research and education**
The establishment of coordinated programs in STEM Education is our ultimate goal, and we have made significant strides in that direction. The coordination of our efforts have led to many new faculty projects, opportunities for graduates and undergraduates to engage in STEM education. Finally, these efforts have been cited as a national model for programs in STEM education (e.g. APLU national Science and Mathematics Teacher Imperative).

**Contributions to other aspects of public welfare beyond science and engineering, such as commercial technology, the economy, cost-efficient environmental protection, or solutions to social problems**
In particular we investigate how we might encourage undergraduate physics majors to become precollege teachers (the LA program) and how, more broadly, education can be infused in the culture of physics through our community partnerships programs. These programs are becoming national models, as cited by the American Physical Society and the Association for Public and Land-grant Universities, for transforming undergraduate math and science and the recruitment and preparation of future STEM teachers.